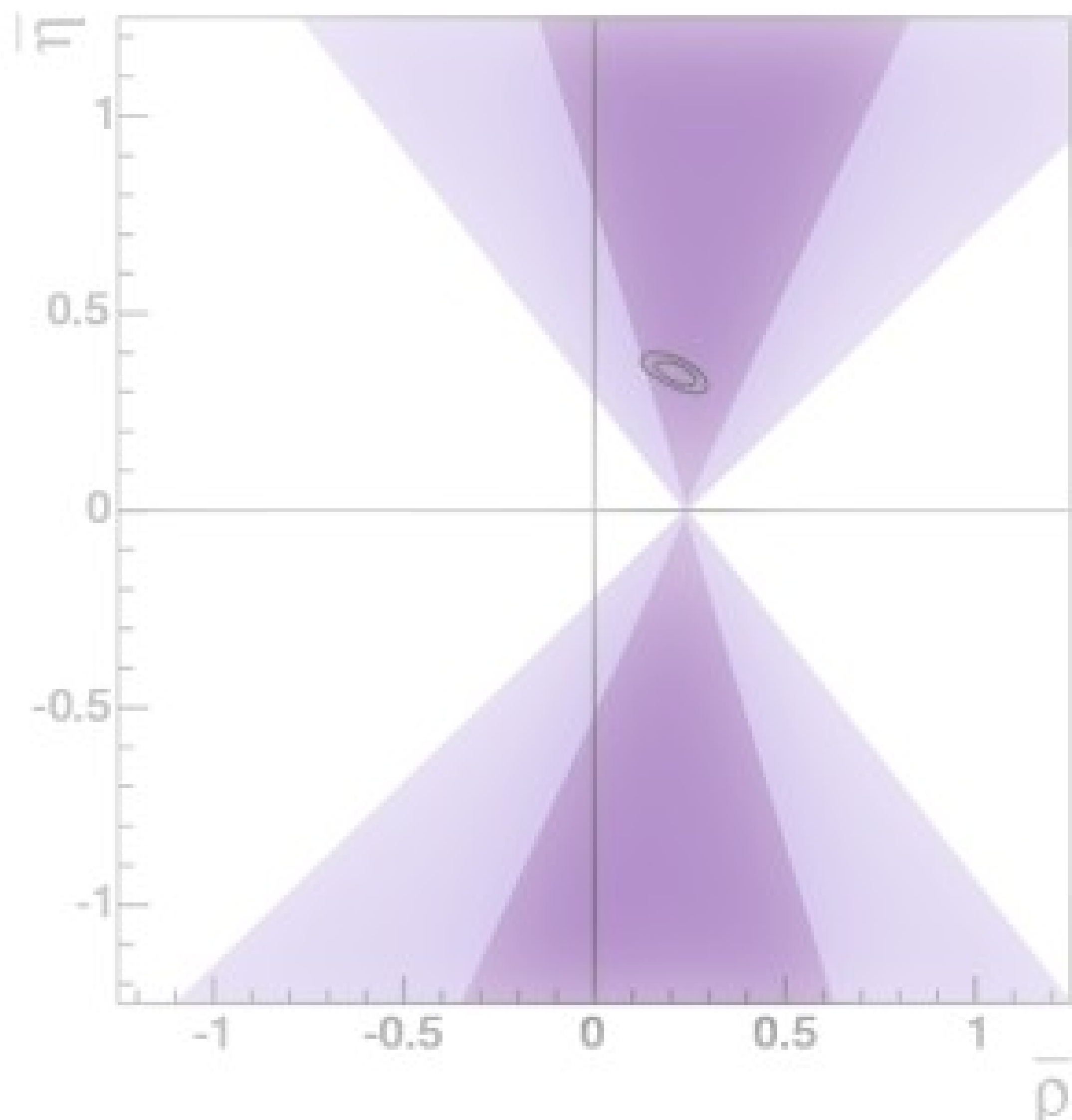
A new bound on the CKM matrix from $K \pi \pi$ Dalitz plots



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CPS, hep-ph/0601233

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$B \to K^* \pi$ Decay Amplitudes

Charming Penguin $\sim \lambda^2$ | $V_{us} V_{ub}^* \sim \lambda^4$

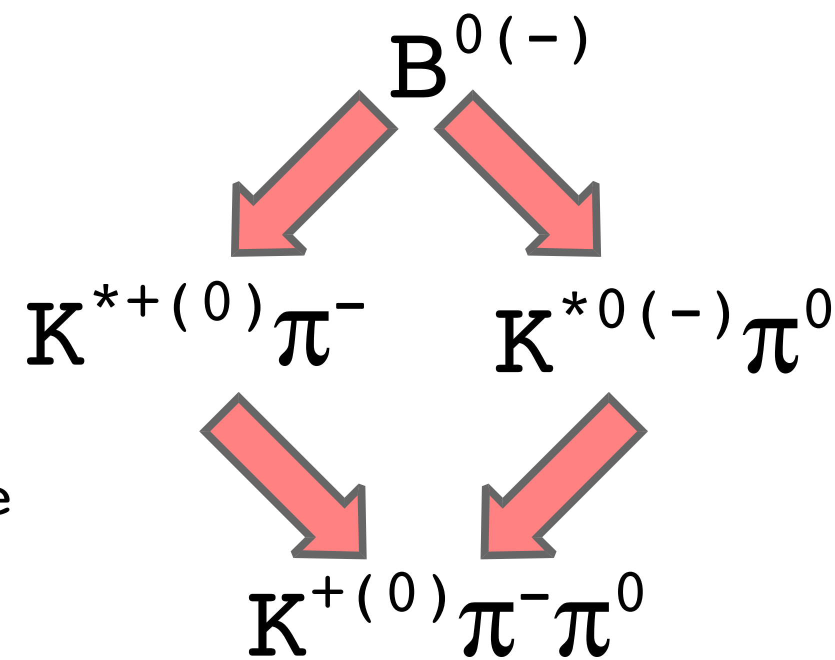
$$A(B^0 \to K^{*+} \pi^-) = V_{ts} V_{tb}^* \times P_1 - V_{us} V_{ub}^* \times \{E_1 - P_1^{GIM}\}$$

$$\sqrt{2}\, A(B^0 \to K^{*0} \pi^0) = -V_{ts} V_{tb}^* \times P_1 - V_{us} V_{ub}^* \times \{E_2 + P_1^{GIM}\}$$

$$\sqrt{2}\, A(B^+ \to K^{*+} \pi^0) = V_{ts} V_{tb}^* \times P_1 - V_{us} V_{ub}^* \times \{E_1 + E_2 + A_1 - P_1^{GIM}\}$$

$$A(B^+ \to K^{*0} \pi^+) = -V_{ts} V_{tb}^* \times P_1 + V_{us} V_{ub}^* \times \{A_1 - P_1^{GIM}\}$$

- Buras-Silvestrini RGI parameters
- Same parameters in all decay modes assuming isospin symmetry
- real and imaginary parts of the amplitudes measurable through the interference in Dalitz plots



A new bound on the CKM Matrix

It is possible to experimentally access $\Delta I=3/2$ amplitude

from $K^+\pi^-\pi^0$ Dalitz plot

$$A^0 = A(K^{*+}\pi^-) + \sqrt{2}\,A(K^{*0}\pi^0) = -V_{ub}^* V_{us}(E_1+E_2)$$

$$A^+ = \sqrt{2}\,A(K^{*+}\pi^0) + A(K^{*0}\pi^+) = -V_{ub}^* V_{us}(E_1+E_2)$$

from $K^0\pi^+\pi^0$ Dalitz plot

The ratio of these amplitudes and their CP conjugates measures γ

The same argument applies to higher K* resonances

$$R^0 = \frac{\bar{A}^0}{A^0} = \frac{V_{ub} V_{us}^*}{V_{ub}^* V_{us}} = e^{-2i\gamma} = \frac{A^-}{A^+} = R^{\mp}$$

Back to real life (I)

The relative phase between B and $\overline{B}$ decays is not measurable from the two considered Dalitz plots (i.e. there are two independent arbitrary phases)

How do we pin down this relative phase?

- **For $K^+\pi^-\pi^0$**
  - the relative phase Δ can be measured in the CP eigenstate Dalitz plot $B\to K_S\pi^+\pi^-$, where B and $\overline{B}$ decays indirectly interfere

In this way we get

$$R^0 = e^{-2i\gamma - i[\Delta - Arg\, A(K^{*-}\pi^+) + Arg\, A(K^{*+}\pi^-)]}$$

Back to real life (II)

✯ For $K^0\pi^-\pi^0$

- **isospin-based method:** one can use the SU(2) relation

$$A^0 = A(K^{*+}\pi^-)+\sqrt{2}A(K^{*0}\pi^0) = \sqrt{2}A(K^{*+}\pi^0)+A(K^{*0}\pi^+) = A^+$$

in this way the sensitivity to CKM terms is lost to indirectly determine the strong phase difference. But we still have the other K* resonances.

- **Model-dependent method:** since $K^{*0}\pi^+$ is penguin dominated, one can write

$$Arg(A(K^{*0}\pi^+))=\beta_s+Arg(1+\frac{V_{ub}^*V_{us}}{V_{tb}^*V_{ts}}\Delta_+e^{i\delta_+})$$

$\Delta_+=(A_1-P_1^{GIM})/P_1$ is $O(1)$ correction, the ratio of CKM terms is $O(\lambda^2)$, and the dependence on $\bar{\rho}$ and $\bar{\eta}$ is known

Inclusion of EW Penguins (I)

EWP's are suppressed $\sim\alpha_e/\alpha_s$ wrt strong penguins but are enhanced by λ^{-2} wrt $\Delta I=3/2$ amplitudes to which they give an O(1) correction.
Fortunately:

- **Q_7 and Q_8 can likely be neglected, since $|C_{7,8}| \ll |C_{9,10}|$**
- **Q_9 and Q_{10} can be eliminated from the H_{eff} at the operator level (no SU(3) required)**

$$Q_9 = \frac{3}{2}\left(Q_1^{suu} - Q_1^{scc}\right) + 3Q_1^{scc} - \frac{1}{2}Q_3^s \quad ; \quad Q_{10} = \frac{3}{2}\left(Q_2^{suu} - Q_2^{scc}\right) + 3Q_2^{scc} - \frac{1}{2}Q_4^s$$

$$H_{eff} \propto \left(V_{ub}^* V_{us} C_1 - \frac{3}{2} V_{tb}^* V_{ts} C_9\right)\left(Q_1^{suu} - Q_1^{scc}\right) + \left(V_{ub}^* V_{us} C_2 - \frac{3}{2} V_{tb}^* V_{ts} C_{10}\right)\left(Q_2^{suu} - Q_2^{scc}\right) - V_{tb}^* V_{ts} H_{QCDP}^{\Delta I=1/2}$$

Inclusion of EW Penguins (II)

The effect of the EWP's on the $\Delta I=3/2$ amplitudes is accounted for by a single parameter

$$\kappa_{EW} = -\frac{3}{2}\frac{C_9+C_{10}}{C_1+C_2}\frac{V_{tb}^* V_{ts}}{V_{ub}^* V_{us}} = \frac{3}{2}\frac{C_9+C_{10}}{C_1+C_2}\left(1+\frac{(1-\lambda^2/2)^2}{\lambda^2(\bar{\rho}+i\,\bar{\eta})}\right)$$

They contribute to the ratios R as

$$R^0 = R^{\mp} = e^{-2i\gamma + Arg(1+\kappa_{EW})}$$

The constraint is no longer on γ but is a linear relation between ρ and η

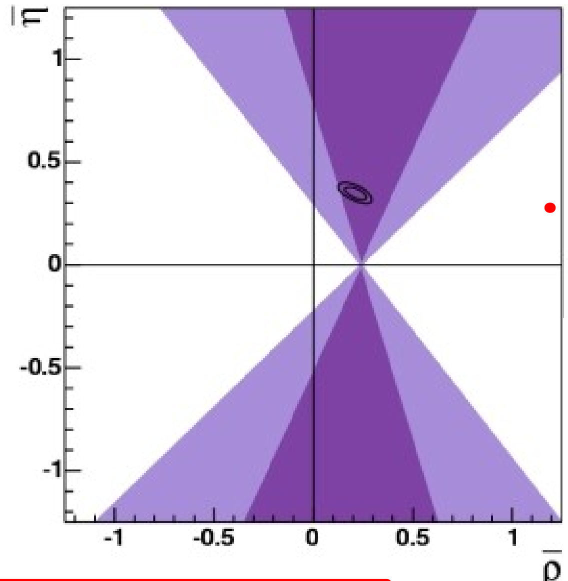
$$\bar{\eta} = -\tan\left(\frac{1}{2}Arg\,R^0\right)(\bar{\rho}-\bar{\rho}_0)$$

Bound on CKM from Arg(R^0)

BaBar, hep-ex/0408073

Arg(R^0) is already measured with an error of 18°.
We do not have the $K_s\pi\pi$ Dalitz plot yet, so the relative phase of B and $\bar{B}$ cannot be fixed.

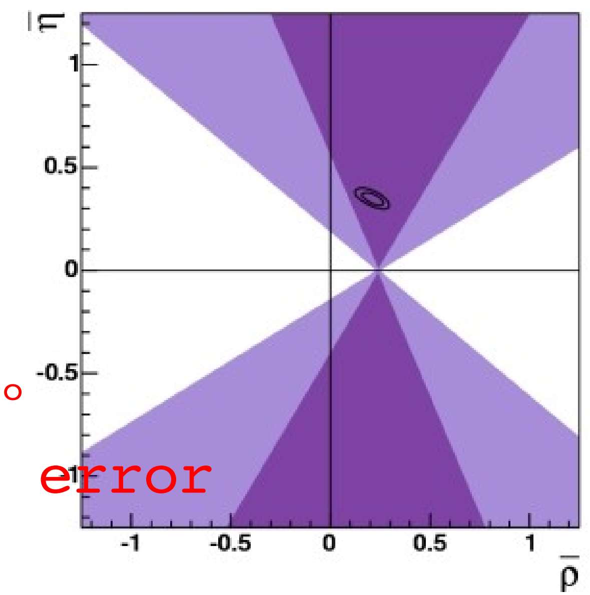
We can assume **a perfect agreement to SM and ...**



...20° of error

Precision would be already comparable to γ from DK

$$\bar{\rho}_0 = -\frac{3(C_9+C_{10})}{2(C_1+C_2)+3(C_9+C_{10})}\frac{(1-\lambda^2/2)^2}{\lambda^2}$$



...40° of error

What New Physics can do

(assuming that NP does not enter at tree-level)

NP changes the coefficients of QCDP's

The analysis of R^0 is unchanged, NP modifies the constraint from $R^\pm$, possibly making them incompatible

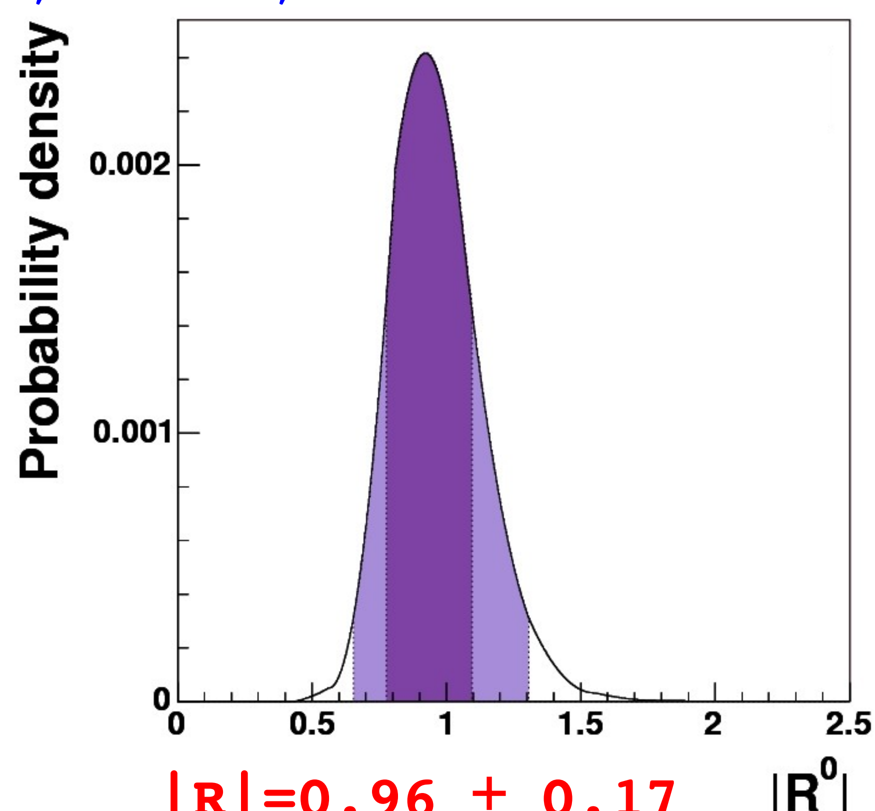
NP changes EWP's (respecting $C_{7,8} \ll C_{9,10}$)

The phase of κ_{EW} would change, breaking the SM relation between Arg(R) and $\bar{\rho}$, $\bar{\eta}$

NP modifies the hierarchy among EWP's ($C_{7,8} \sim C_{9,10}$)

the additional $\Delta I=3/2$ operator would break the relation between R and $\bar{\rho}$, $\bar{\eta}$.

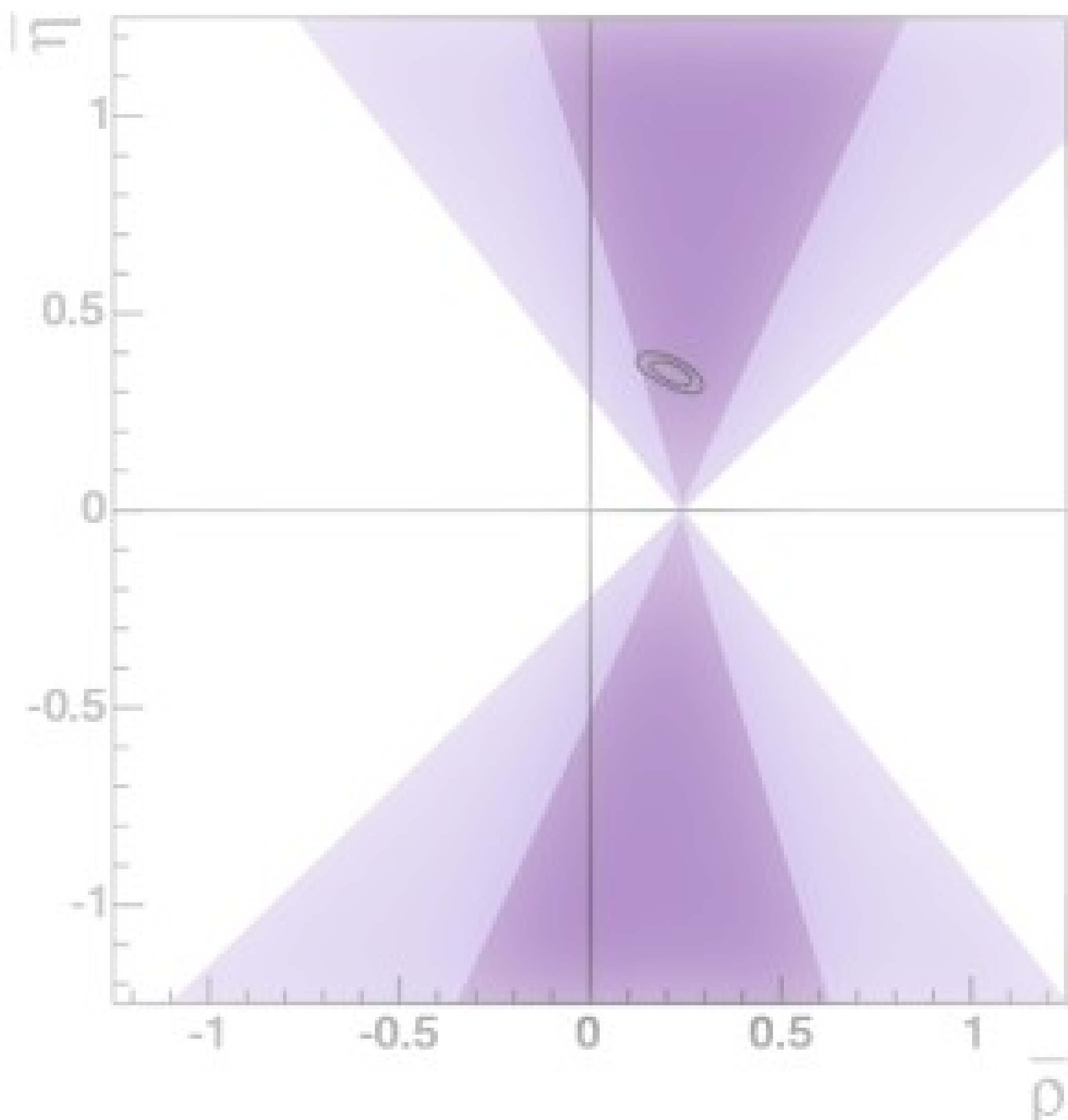
In particular, $|R| \neq 1$ is expected



$|R| = 0.96 \pm 0.17$

Conclusions

There is a new bound on the CKM matrix



Conclusions

There is a new bound on the CKM matrix

$$\bar{\eta} = -\tan\left(\frac{1}{2}\, Arg\, R^{0}\right)(\bar{\rho} - \bar{\rho}_0)$$

Let's use it!!!